Appendix B
Materials Analysis:
Paint
Mortar and Salts

Historic Building Architects, LLC

APPENDIX B - MATERIAL ANALYSIS

PAINT ANALYSIS

Summary of Findings

Seventeen paint samples from the exterior wood surfaces at the First Unitarian Society of Plainfield New Jersey were taken. Sample number six was destroyed, thus sixteen paint samples from the site were analyzed to determine the original color schemes of the major building campaigns of the church.

The results show that the exterior wood work of the 1892 church was a pink/buff color similar to that of the original pointing mortar. This paint layer darkened to mauve with age. The mauve theme was remembered and repeated several times, and each new addition was painted some variation of mauve the first time that it was painted.

Introduction

The purpose of paint analysis is to understand the original colors and design intentions of the architect, to understand the chronology of construction, and to identify replaced or repaired historic fabric. Knowledge of how the structure has been used, how buildings and architectural elements deteriorate, and the historical use of paints and architectural finishes assist in locating proper paint samples, in the analysis of the samples, and in the understanding of the paint layers that are exposed during the procedure. The wood surfaces of the exterior of the First Unitarian Church were painted. This included window and door trims, the cornices, porches, shingles, and shutters.

Investigation of the exterior wood finishes is part of a larger conservation program for the First Unitarian Society of Plainfield New Jersey, by Historic Building Architects, LLC. Christina Burris, HBA's Architectural Materials Conservator, collected the paint samples on September 27th, 2007. Cross sectional analyses were conducted on sixteen of the seventeen samples collected from the church.

Analyses were done at HBA's in house laboratory. Visual microscopic examination and analysis of the paint stratigraphy were done using a Nikon SMZ1000 stereo microscope with reflected light.

Definitions

The following terms will be useful in the understanding of the paint analysis report.

Layer: A single stratum of paint found in the overall stratigraphy of paint revealed by the micrograph.

Micrograph: The photograph showing the paint sample under low magnification (10x-80x).

Campaign: All of the layers applied to create one finish. A campaign may contain one or several layers of paint, including a primer and a finish coat.

Methodology

Sampling in carefully selected locations gives a higher probability of revealing the original paint campaigns. Samples were taken from between shingles, and areas that may not have been aggressively cleaned as much as possible. The samples were then embedded in a mounting medium (Bio-plast®) and cross-sectioned with a Buehler Isomet high precision diamond saw. The complete sample list with location and brief description is included at the end of this section and titled "paint samples." Of the sixteen, this report focuses on five samples representing the original paint campaign.

The following visual and analytical techniques were used to characterize and interpret the paint campaigns:

- **Visual Examination and Color Notation**
  The colors of all the paint layers in cross-section were notated and compared to the Munsell system standards (ASTM D1535-97) and to Benjamin Moore paint colors.

- **Reflected Light Microscopy (RLM)**
  Cross-sectional specimens embedded in Bio-plast® were investigated at low magnification under reflected light to determine paint campaigns.

- **Historical Research**
  First Unitarian Society of Plainfield historic photographs were reviewed to understand the architectural evolution and configuration of the buildings. Evidence of paint campaigns aided in the understanding of the chronology of construction. Regional historic technology and traditional exterior wood finish treatments typical for the period of construction were used to interpret the analytical results.

Results

The goal of this investigation is two fold. First, to understand the original exterior color schemes for the wood surfaces. Second, to provide recommendations for restoration of finishes in accordance with the recommended period of restoration.

The earliest available paint layer seen in the old church is a buff color that matches the modern Benjamin Moore paint color Brentwood 1223. This color is similar to, but slightly darker than the color of the original mortar used in the church. The original paint campaign is followed by a lighter shade of pink that appears to have darkened to a grey/mauve color over time. Such color changes are typically found in paints due to UV damage, pigment shifts, and dirt layers. The exterior woodwork of the First Unitarian Church of Plainfield was subsequently painted pale shades of olive green, followed by ocher before the mauve and pink campaigns were repeated. The exterior color scheme of the church darkened in the second half of the twentieth century with dark oranges and red browns before a dark green was settled on. Various shades of dark green have been applied to the woodwork of the church in recent history.

The second pale pink paint campaign found on the church woodwork may have been remembered when additions were made to the structure. Both the Parish Hall and Stevens Wing were originally painted a variation of mauve similar to the darkened outer zone of the pale pink layer. The shingles on the exterior of Parish Hall were the same as the modern Benjamin Moore paint color, Davenport Tan 8C-76. Several layers above the Davenport Tan is a slightly greyer shade of Mauve that is also the first paint layer found on the Stevens Wing. This color is the same as the modern Benjamin Moore paint color Greystone 1475. There is one last remaining original window frame found on Parish Hall. The first layer found on this woodwork is the Greystone 1475. Windows frequently need to be repainted, and it is not surprising that the original paint color could not be found, but the presence of the Greystone layer indicates that there was an attempt to keep the window frames the same color as the surrounding shingles.

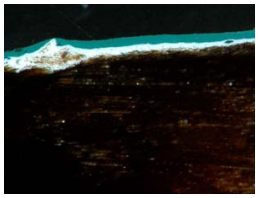
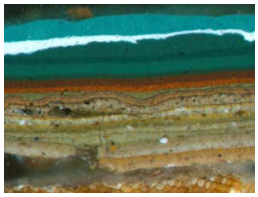
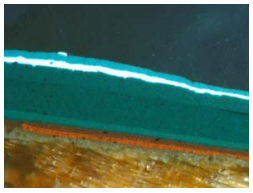
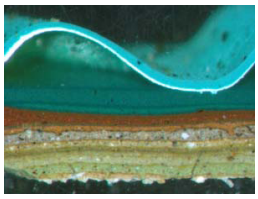
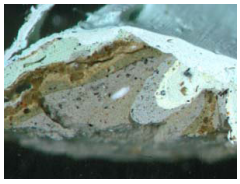
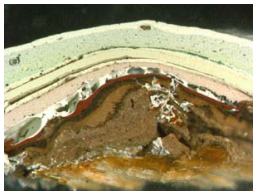
Recommendation

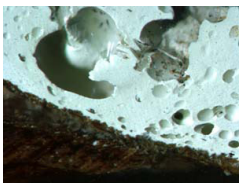
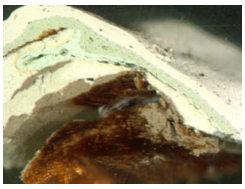
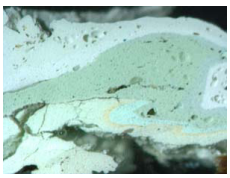
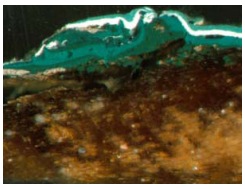
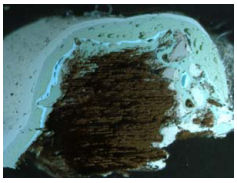
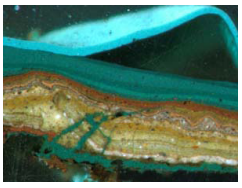
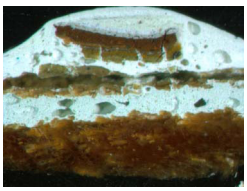
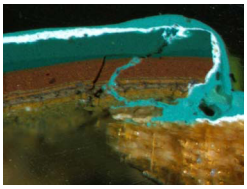
1. Buff - 1892 Wood work
Munsell number: 7.5 YR 5/4
Benjamin Moore number: Brentwood 1223

2. Mauve- Parish Hall
Munsell number: 2.5 Y 5/2
Benjamin Moore number: Davenport Tan 8C-76

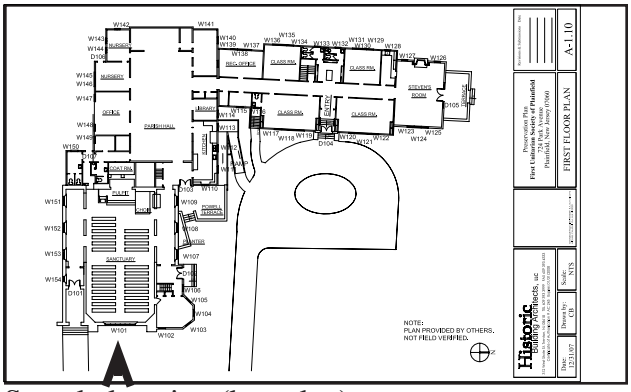
3. Mauve- Stevens Wing
Munsell number: 10 YR 6/1
Benjamin Moore number: Greystone 1475

Schedule of Paint Samples:

No.	Date Sampled	Location of Sample	Photo-micrograph	1st Paint Layer	Modern Paint Color
P1	9/27/2007	The Robinson Window Sill		Modern teal	Only modern paint seen, no match made.
P2	9/27/2007	The Robinson Window Frame		Buff	Brentwood 1223
P3	9/27/2007	The Robinson Window Muntin		Buff	Brentwood 1223
P4	9/27/2007	Robinson Window Mortar Bead		Mauve	The 1st paint layer is the same as later additions. The mortar bead itself may be a repair or later addition.
P5	9/27/2007	Church Window # 104		Buff	Brentwood 1223
P7	9/27/2007	Church Cornice		Buff	Brentwood 1223
P8	9/27/2007	Parish Hall East Facade Shingles		Mauve	Davenport Tan 8C-76
P9	9/27/2007	Underside of Parish Hall Porch Over Entrance		Pale translucent gold varnish or lacquer	_____

P10	**9/27/2007**	**Parish Hall Shingles Over Wheelchair Ramp**		**Mauve**	**Davenport Tan 8C-76**
P11	**9/27/2007**	**The Stevens wing link East Facade Shingles**		**Mauve**	**Greystone 1475**
P12	**9/27/2007**	**Stevens wing Shingles**		**Mauve**	**Greystone 1475**
P13	**9/27/2007**	**Stevens wing Day care Entrance**		**Modern greens**	**Only modern paint seen, no match made.**
P14	**9/27/2007**	**Parish Hall Window Frame**		**Mauve**	**Davenport Tan 8C-76**
P15	**9/27/2007**	**Church Window # 106**		**Buff**	**Brentwood 1223**
P16	**10/16/2007**	**Back Wall of Church Roof Level**		**Mauve**	**Brentwood 1223**
P17	**10/16/2007**	**Church Center Dor-mer Frame South Elevation**		**Mauve**	**Brentwood 1223**

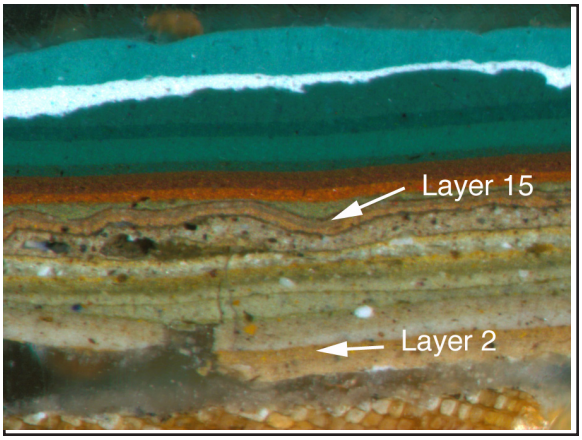
Robinson Window Muntin			
P3	Color	Description	Campaign and Possible Age
Substrate	Wood		
Layer 1	White	Base coat	
Layer 2	Pale pink/buff		
Layer 3	Darker buff		1892
Layer 4	Pale pink		
Layer 5	Mauve		
Layer 6	Pale green/grey		
Layer 7	Pale green		
Layer 8	Dark olive green	Darkened zone of layer 7	
Layer 9	Gold/ocher		
Layer 10	Gray white		
Layer 11	Gold ocher		
Layer 12	Mauve		
Layer 13	Dirt layer		
Layer 14	Coral pink		
Layer 15	Mauve		1925
Layer 16	Dirt layer		
Layer 17	Olive green		
Layer 18	Orange		
Layer 19	Red brown		
Layer 20	Dark green		
Layer 21	Jungle green		
Layer 22	Darker green		
Layer 23	White		
Layer 24	Blue green		



Sample location (key plan)

The removal of the sample from the window muntin.

The church as it appeared in the early 20th century.



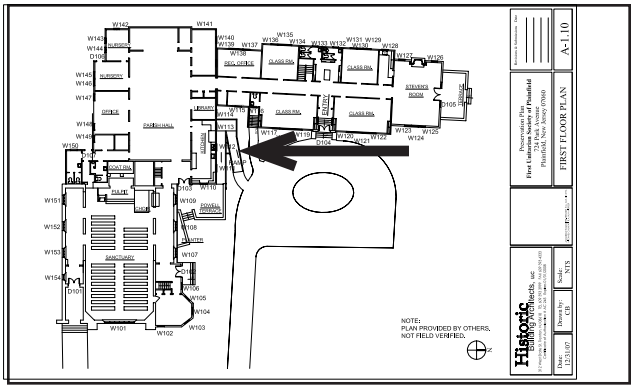
Benjamin Moore # Brentwood 1223

Paint sample P3 taken from the Robinson window muntin seen at 80x.

Notes and Comments:

Layer 2 is the finish coat of the first painting campaign. Layer 15 shows the finish coat applied with the 1925 addition of the parish hall.

Taken from between the shingles on the east façade of the Parish hall			
P8	Color	Description	Campaign and Possible Age
Substrate	Wood	Missing	
Layer 1	Mauve	Similar to layers found on wood elements of the church	
Layer 2	Lighter mauve		1925
Layer 3	Olive green		
Layer 4	Pale yellow tan		
Layer 5	Brown	Heavily pigmented	
Layer 6	Grey	Same as the first layer on the Stevens Wing	1958
Layer 7	Creamy Yellow		
Layer 8	Darker Yellow		
Layer 9	Lime green		
Layer 10	Very pale blue, nearly white		
Layer 11	White		



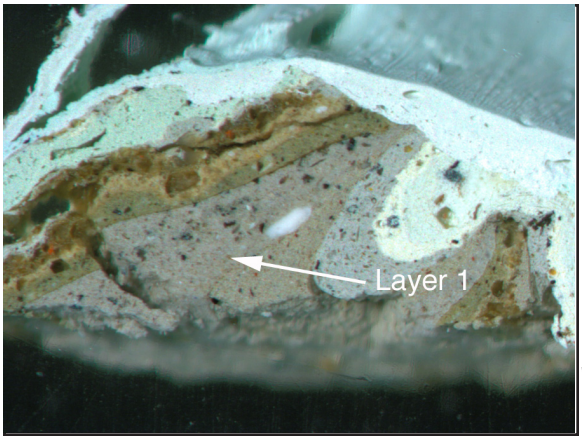
Sample location (key plan)

Sample location on the east facade of the Parish Hall.

Notes and Comments:

The sample floated above the wood substrate during the embedding procedure. Layer 1 was the first layer above the wood substrate.

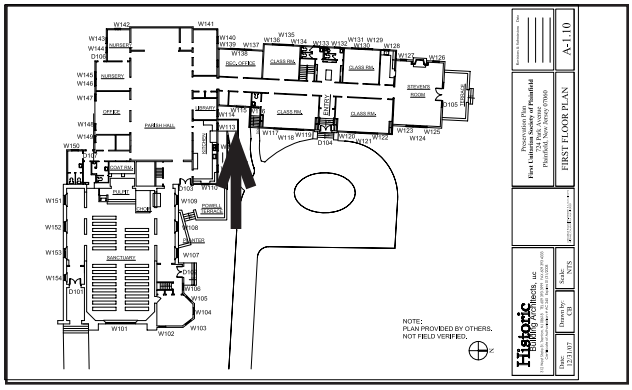
Layer 1 is the same as layer 15 in sample P3 from the 1892 church.



Benjamin Moore #
Davenport Tan
8C-76

Sample P8 seen at 50x.

Taken from the shingles on the east façade of the Parish Hall Link			
P11	Color	Description	Campaign and Possible Age
Substrate	Wood		
Layer 1	Mauve		1958
Layer 2	White		
Layer 3	Creamy yellow		
Layer 4	Pale blue, nearly pale green or white		
Layer 5	Pale green		
Layer 6	White		

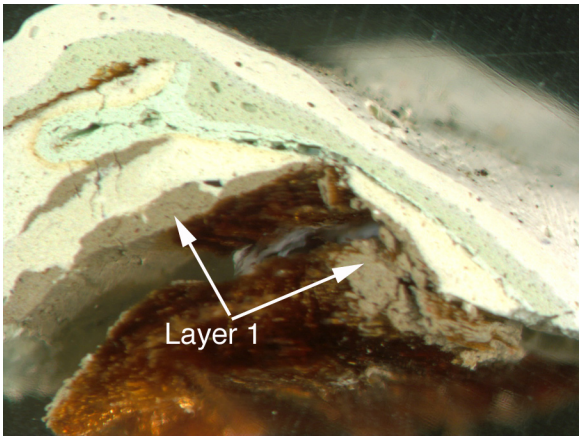


Sample location (key plan)

Sample location on the east facade of the Parish Hall Link.

Notes and Comments:

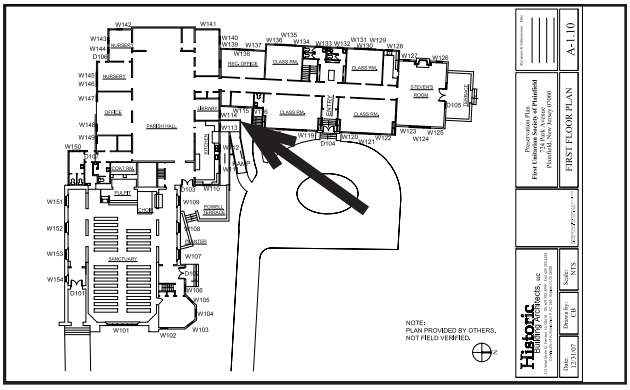
The first paint layer seen is a variation of the mauve used previously on the church and Parish Hall.



Benjamin Moore # Greystone 1475

Sample P11 seen at 40x.

Taken from the last old window of the north façade of Parish Hall			
P14	Color	Description	Campaign and Possible Age
Substrate	Wood		
Layer 1	Mauve		1925
Layer 2	Pale olive green		
Layer 3	Pale blue, nearly white		
Layer 4	Pale olive green		
Layer 5	Very pale tan/ olive green		

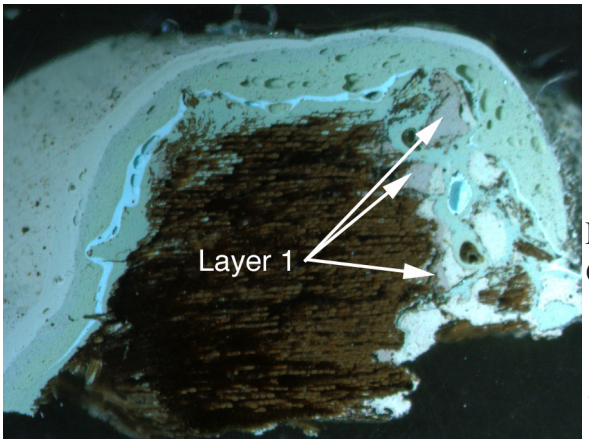


Sample location (key plan)

Notes and Comments:

The sample was taken from the last remaining window on the east facade of Parish Hall. The lower part of window frames are particularly subject to rot due to pooling moisture and splashing as rain splatters on the sill. For this and other environmental reasons window frames are prone to paint deterioration and may need to be painted frequently. The oldest layer found in sample P14 has been broken up due to environmental reasons or aggressive cleaning. Fragments of the first layer were picked up by the paint brush during subsequent paint campaigns, and distributed throughout later paint layers.

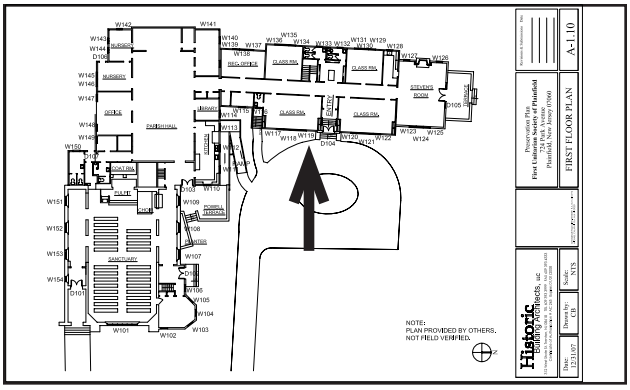
The first layer seen in sample P14 is the same as that seen in samples taken from the 1958 Stevens Wing addition. The relatively late first paint layer may be due to the high rate of window paint deterioration.



Sample P14 seen at 20x.

Benjamin Moore # Greystone 1475

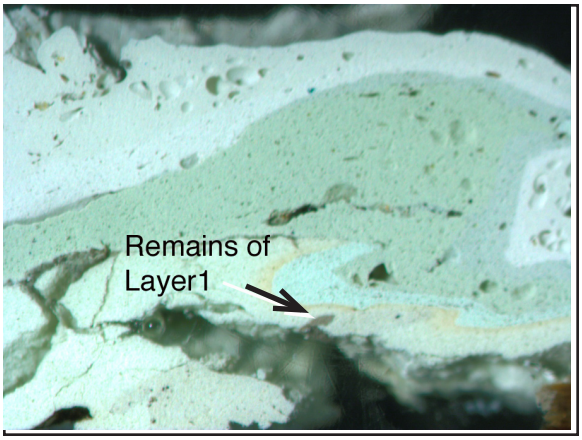
Taken from the shingles on the east façade of the Stevens Wing			
P12	Color	Description	Campaign and Possible Age
Substrate	Wood		
Layer 1	Mauve	There is only a trace of this layer left. It has been destroyed by aggressive cleaning	1958
Layer 2	White		
Layer 3	Creamy yellow		
Layer 4	Pale blue, nearly white		
Layer 5	Pale green		
Layer 6	White		



Sample location (key plan)

Notes and Comments:

Like sample P14, the first layer has been destroyed by aggressive cleaning. A small remnant is all that is left of the first layer at the base of the sample.



Benjamin Moore #
Greystone 1475

Sample P12 seen at 30x.

MORTAR ANALYSIS

Introduction

Material analyses were conducted on the bedding and pointing mortars collected from the exterior of the First Unitarian Society of Plainfield Church in Plainfield, NJ.

The purpose of the mortar investigation was to determine the original mortar composition. The mortar analysis and interpretation are part of a larger Preservation Plan for the First Unitarian Society of Plainfield currently underway by Historic Building Architects, LLC.

Christina Burris removed samples of mortar and analyzed the samples from September through early November 2007. The characterization and compositional analysis of the samples were conducted in the facilities of the Historic Building Architect's Conservation Laboratory.

The objective of the analyses was to characterize the sampled mortars as a means of documenting their constituent materials, describe their original appearance and basic properties, so that they can be better understood and replicated for future repointing campaigns.

Sampling

A thorough investigation of the pointing and bedding mortar sequences were done on site before samples were removed. Six representative samples of mortar were removed. Much of the building had been re-pointed with a mortar that was more cementitious than the mortar beneath it. The wall underneath the portico on the southeast side of the building had been more protected from the elements than the other, more exposed walls. This wall had not been re-pointed with the cementitious mortar. The mortar found here had two distinct layers; the pointing mortar, or the mortar on the outer surface that can be seen, and the bedding mortar, the mortar that is used between the stones when they are laid. In some areas the pointing mortar was separating from the bedding mortar and could be pulled away from the building with a bare hand. In other cases, and with all bedding mortar a mortar and chisel was needed to remove the samples (M2 and M3). Due to the location, condition, color, and texture of the mortar it was presumed that the samples found under the portico were an older mixture than most of the mortar found at the First Unitarian Society of Plainfield. These samples were the samples analyzed. The presumed age of the samples was validated by a sample removed from the basement walls by Annabelle Radcliffe-Trenner on October 16th 2007. The placement of the this sample (M5) indicated that it had been in situ since the building's construction, and it had the same visual composition, color and texture as samples M2 and M3.

List of Analyzed Samples

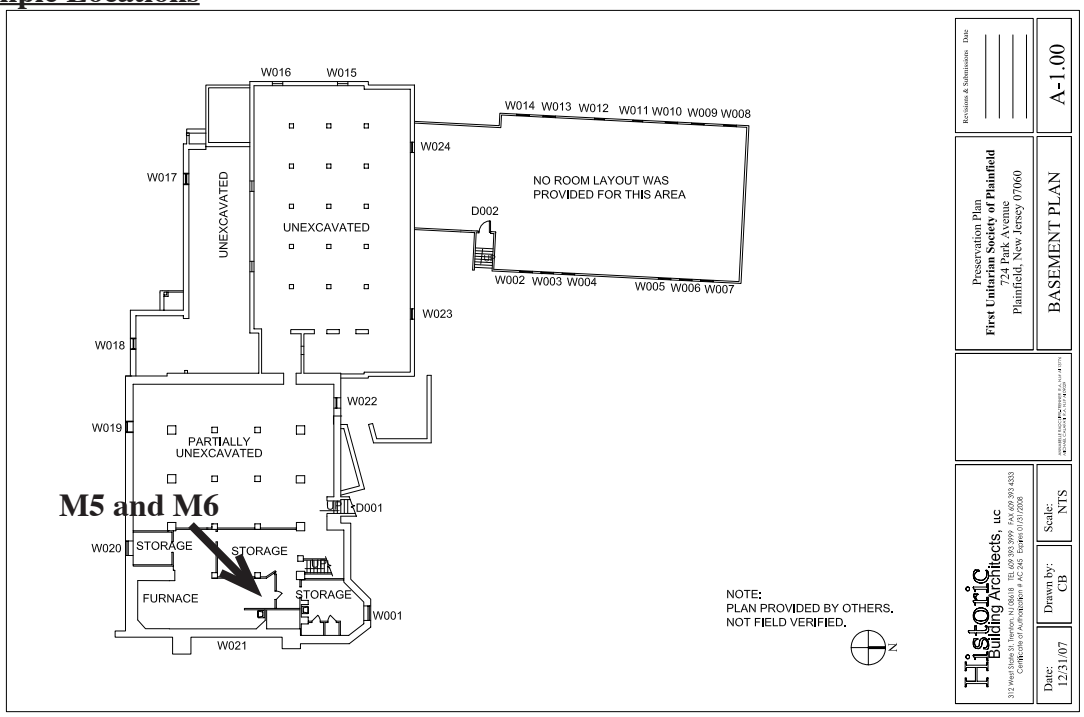
FUSP-M3 – Bedding mortar from exterior
FUSP-M2 – Pointing mortar from exterior

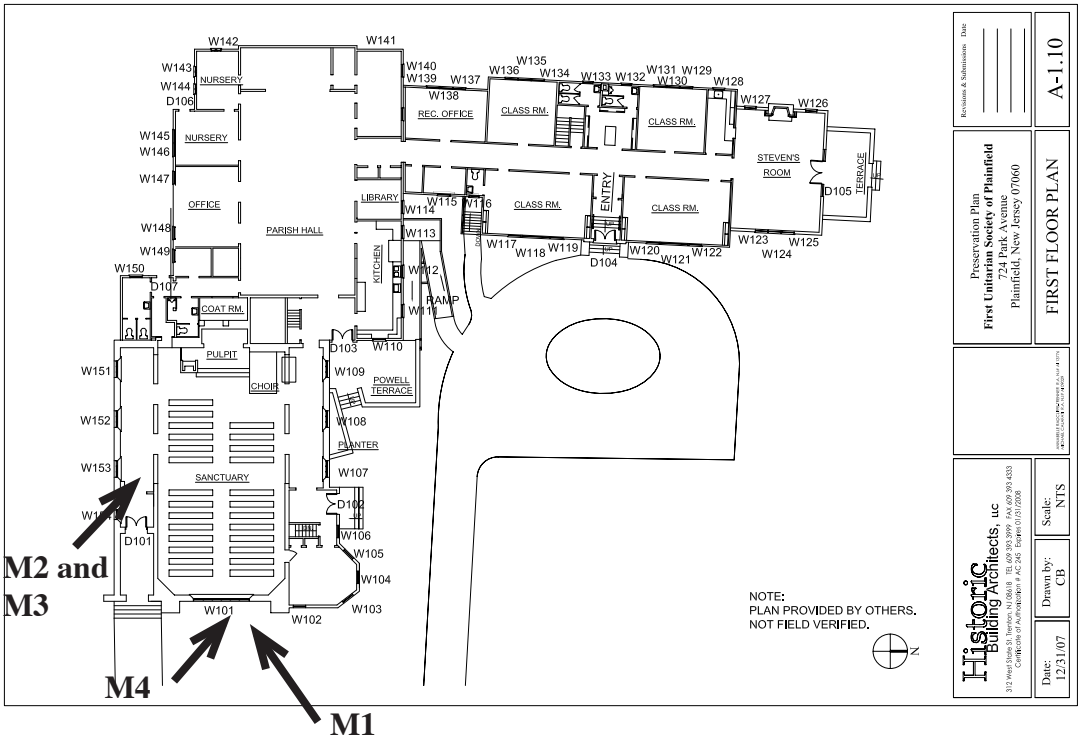
View of pointing mortar before removal

View of sample location after samples M2 & M3 are removed

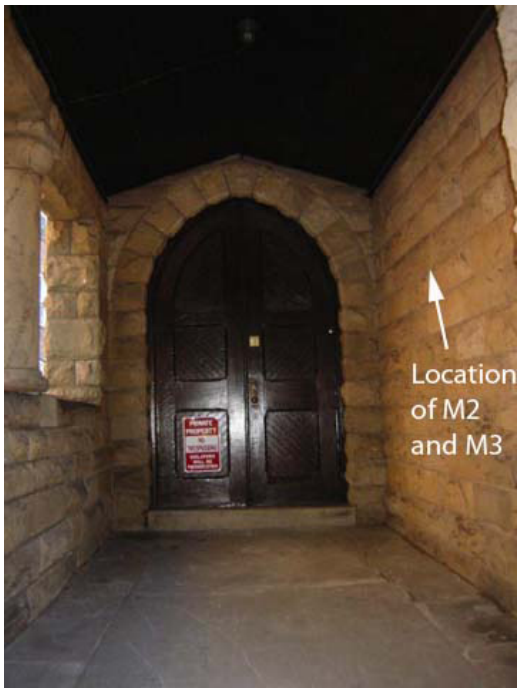
Sample	Date Sampled	Location	Description
M1	9/27/2007	Taken from the 2nd joint of the southeast corner of the Robinson window.	Pointing mortar Cementitious
M2	9/27/2007	Taken from pencil scored joint in southeast vestibule	Pointing mortar from under portico, crumbly
M3	9/27/2007	Taken from joint in southeast vestibule	Bedding mortar, appears to be more lime based
M4	9/27/2007	Joint between the wood board and stone under the Robinson window.	Cementitious
M5	10/16/2007	Basement mortar - east wall	Similar if not the same as M3
M6	10/16/2007	Basement mortar	Same as M5 with efflorescence

Sample Locations





Sample M1 - Cementitious mortar below Robinson window.



Samples M2 and M3 - The pointing and bedding mortar found under the portico on the Park Avenue elevation.

Sample M4 (Left) - Mortar found in the joint between the wood board and masonry wall in the basement window below the Robinson Window.

Samples M5 and M6 (Above) - removed from the interior basement wall.

Methodology

The following visual and analytical techniques were used to characterize the samples:

Color Notation

The color of all samples in fresh cross-section were observed and compared with the Munsell system standards (ASTM D1535-97) using a Munsell Soil Chart.

Gravimetric Analysis

Particle size distribution of the mortar aggregate is determined through sieving the crushed mortar. After sieving, weighing and volumetric measurement of the various fractions they were then examined under reflected light and photographed to document the aggregate shape and type. Aggregate is comprised of gravel (>2.36mm) and sand (2.18mm - 2.36mm); whereas the binder consist of fines between 300μm- 600μm. Standard acid digestion of the samples was performed by using 14%HCl. The results were separated into its three constituent components: the acid-soluble fraction, the "fines" (pigment, cement, or clay residue), and the sand/gravel fraction (aggregate).

Reflected Light Microscopy (RLM)

This technique was used for the examination of a freshly broken surface of each sample that was viewed under a variable zoom, stereo-binocular microscope Nikon SMZ1000. The predominant colors, shapes and average size of the sand grains were noted and photographed during microscopic examination of the sieved fractions sample was embedded in a Bioplast Resin,®, the cross-section was photo-micrographed at a low magnification under reflected light.

Results

The exterior of the Church is made up largely of mortar sample M1, which is a grey color and most likely contemporary probably dating to the 1981 restoration of the Church. The softer, lighter mortar found on the masonry wall beneath the porch on the Park Avenue elevation appeared to be older than the more predominant grey mortar. This assumption was based on its condition, softer lime mortar like appearance, and its sheltered position under the porch. A bedding mortar sample (M2) and a pointing mortar sample (M3) were removed from this wall.

Bedding mortar is the mortar used between stones, while pointing mortar is the outer layer of mortar that can be seen on the exterior of the masonry.

Historically bedding and pointing mortar were of the same mix, but while microscopic analysis of samples M2 and M3 showed the two mixes to be very similar, they are not the same. The bedding mortar is a lime based mortar, light grey in color. The pointing mortar contains cement in the mix and is a slight variation in color, light grey brown. Both samples showed the same red brown aggregate of crushed brick and/or rounded bits of sandstone and larger pieces of rounded quartz. The pointing mortar has the additional pieces of angular aggregate and grains of Portland Cement that were broken up during the grinding process but were never dissolved like the more soluble lime.

The bedding mortar is a lime mortar with a 1:3 ratio of lime to aggregate. The pointing mortar contained cement that was not completely broken down by the grinding process and acid dissolution used in gravimetric analysis. When the aggregate was sieved after the gravimetric analysis, some of the gravel in screens 8 and 12 contained what should have been smaller aggregate bonded together into larger pieces by cement. This may have thrown off the aggregate to cement to lime ratio. The pointing mortar may therefore be a Type O or N mortar. This mortar would contain 1 part cement, 1 to 2 parts lime, and 5 to 9 parts aggregate.

The difference is the bedding and pointing mortar may be explained in one of three possible ways:

1. When the building was constructed a more durable mortar was used for the pointing mortar.
2. The original mortar failed soon after construction. The aggregate that was used in the first mortar was still available and chosen for the new pointing mortar.
3. A Mortar Analysis was conducted in recent memory to create a replacement mortar. The aggregate in both mortars is remarkably similar. This must be due to either intentional matching by a mason informed by a mortar analysis, or because the mortars were mixed and used in quick succession.

It is strongly recommended that any future repointing methods recreate these mortars, matching in color, texture, and type based on this analysis.

Mortar Analysis Table					
Project/Site: **First Unitarian Society of Plainfield**					
Location: Plainfield, New Jersey			Date Sampled:September 2007		
Analysis performed by: Christina Burris			Date analyzed:November 2007		
Description of Sample			**Sample No.# FUSP-M2**		
Type/Location: Exterior pointing mortar					
Surface appearance: Pinkish brown pencil scored joint					
Cross Section/Layering: None					
Color: (10 YR 7/3)		Texture: 120-220 grit			
Hardness: Medium Hard		Gross Wgt: 36.1			
Components					
Gravimetric Analysis	Fines:	Color: 10 R 6/1	Wgt: 3.33g	% Wgt: 10.46	
		Organic Matter: None			
	Acid Soluble Fraction:	Filtrate Color: Pale Gold	Wgt: 10.96g	% Wgt: 34.44	
		Description of Reaction: Medium effervescence			
	Aggregate:	Color: 2.5 YR 5/1-3	Wgt: 17.55g	% Wgt: 55.1	
		Grain Shape: Sub-angular to Sub-rounded (more platy than M3)			
		Mineralogy: Bits of brick, quartz, sand, and flakes of Portland cement			
		Sieve Analysis *After Acid*	Screen	g Retained	
			8	0.65	
			12	0.88	
			25	3.61	
			50	7.51	
			100	3.56	
			pan	1.34	
Assessment					
Mortar Type: Possibly type O or N		Fines: 1			
		Acid Soluble: 3.29			
		Aggregate: 5.27			
Notes: This mortar is extremly similar to M3, but the aggregate is more angular and cement has been added to the mix. All the cement was not ground/dissolved, it is possible that some of the binder has been counted as aggregate. Hence, the possibility of type O or N.					

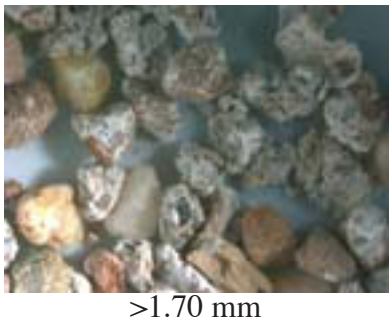
Mortar Analysis Table				
Project/Site: **First Unitarian Society of Plainfield**				
Location: Plainfield, New Jersey			Date Sampled: September 2007	
Analysis performed by: Christina Burris			Date analyzed: November 2007	
Description of Sample			**Sample No.# FUSP-M3**	
Type/Location: Exterior bedding mortar				
Surface appearance: Pinkish binder rich mortar				
Cross Section/Layering: None				
Color: (5YR 7/1)		Texture: 120-220 grit		
Hardness: Medium Hard		Gross Wgt: 35.53		
Components of Methodology				
Gravimetric Analysis	Fines:	Color: Light grey/pinkish grey (7.5YR 7/1-3)	Wgt: 2.77g	% Wgt: 7.79%
		Organic Matter: None		
	Acid Soluble Fraction:	Filtrate Color: Pale Gold	Wgt: 8.82g	% Wgt: 24.82%
		Description of Reaction: Medium Effervescence		
	Aggregate:	Color: 10R4/3 - 2.5YR4/3	Wgt: 23.94g	% Wgt: 67.38%
		Grain Shape: rounded to sub-angular		
		Mineralogy: Broken brick or sandstone noted, quartz		
		Sieve Analysis *After Acid*	Screen	g Retained
			8	1.33
			12	0.86
			25	4.66
			50	10.06
			100	5.82
			pan	1.21
Assessment				
Mortar Type: Lime Mortar		Fines: 0.31		
		Acid Soluble: 1		
		Aggregate: 2.71		
Notes:				

First Unitarian Society of Plainfield
Sieved Fractions Under Low Magnification

M2

Nikon
SMZ 1000

>2.36 mm

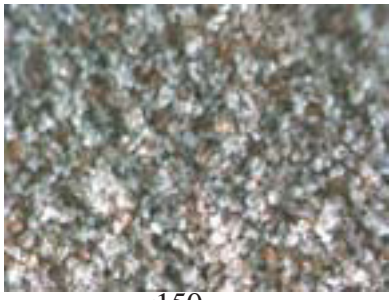


>1.70 mm

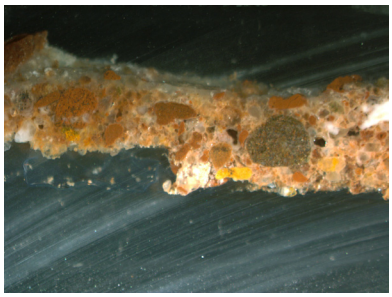
>0.71 mm

>300 µm

>150 µm



<150 µm



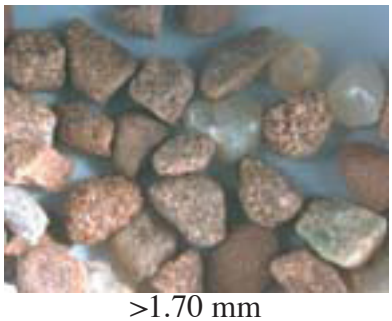
Cross section of M6, basement bedding mortar.

First Unitarian Society of Plainfield
Sieved Fractions Under Low Magnification

M3

Nikon
SMZ 1000

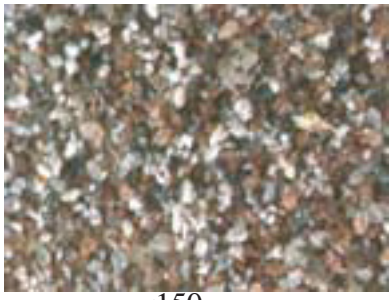

>2.36 mm


>1.70 mm


>0.71 mm


>300 µm


>150 µm


<150 µm

SALT ANALYSIS

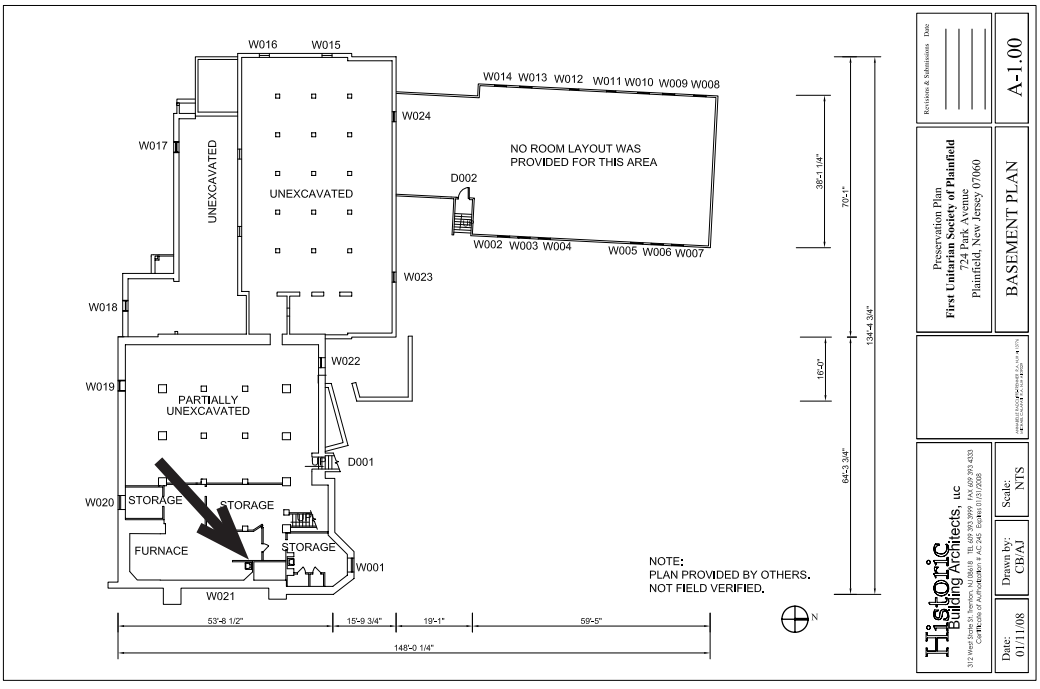
Introduction

Salt deposits on the mortar, especially on the stone walls of the basement of the church were observed and raised as a concern during a site visit on October 16th by the architect. A crust of efflorescence in the basement of the church, just to the south of the Robinson Window was removed by Annabelle Radcliffe-Trenner. The salts were then analyzed in the Historic Building Architect's architectural conservation laboratory by Material Conservator, Christina Burris, on December 4th 2007.

The solubility of salt species varies, and as is commonly the case, influenced by the presence of multiple types of salts. This means that different salt types will crystallize at different heights on the same wall. For this reason it is common practice to test samples taken at regular vertical intervals along a masonry unit.[1]

Sampling

The samples were removed from the surface of the church basement masonry at 4' 6" feet from the ground on the east wall. The results therefore represent the salts that were of concern to the architect in this area at the time of removal.



1 Charola, A. Elena. 2000.Salts in the Deterioration of Porous Materials: An Overview. *Journal of the American Institute of Conservation*. 39: 327-343.

Methodology

Initial chemical spot tests were used to test the efflorescence for carbonates (CO_3^{2-}), chlorides (Cl^-), nitrates (NO^{3-}), and sulfates (SO_4^{2-}). Upon the finding of carbonates a test for calcium ions (Ca^+) was added. These tests are as found in *Material Characterization Tests for Objects of Art and Archaeology*.[1]

Carbonates

This analysis tests for carbonates through the presence of Carbon dioxide after the addition of hydrochloric acid. A drop of 3% barium hydroxide aqueous solution is suspended above the effervescing sample after the acid is added. If chlorides are present then carbon dioxide will form and the barium hydroxide will become cloudy.

Chlorides

This test shows nitrates to be present by the production of hydrochloric acid in gaseous form. If chlorides are present the addition of sulfuric acid will create the volatile, acidic hydrochloric gas that can be recorded using a pH test strip.

Nitrates

The sample is placed into solution using concentrated sulfuric acid. If nitrates are present, the addition of iron sulfate will cause the formation of a brown ring around the sample.

Sulfates

If the sample is positive for sulfates and is dissolved in hydrochloric acid, the addition of barium chloride will cause a white precipitate to form. The test will show as few as 50 to 70ppm sodium sulfate, but if a strong precipitate forms very quickly the sulfate reading is high.

Calcium

If calcium is present in the sample the addition of sulfuric acid will form calcium sulfate. When heated the calcium sulfate will precipitate to form gypsum. Gypsum needles can be identified under low magnification.

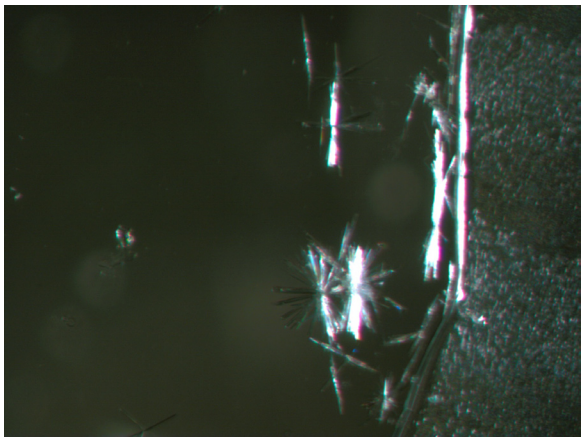
1 Odegaard, Nancy, Scott Carroll, and Werner S. Zimmt, eds. 2005. *Material Characterization Tests for Objects of Art and Archaeology.* London: Archetype Pub.

Findings:

Positive for carbonates

Test for Carbonates:

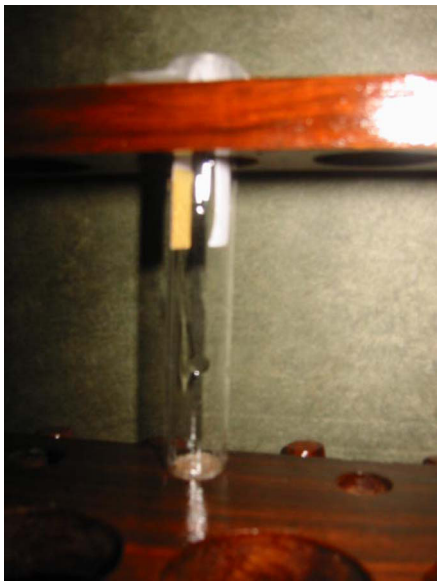
The sample tested positive for carbonates as evidenced by photo 1. The dropper of 3% barium hydroxide ($Ba(OH)_2$) turned cloudy when positioned over the effervescing sample.



Positive for calcium

Test for Calcium:

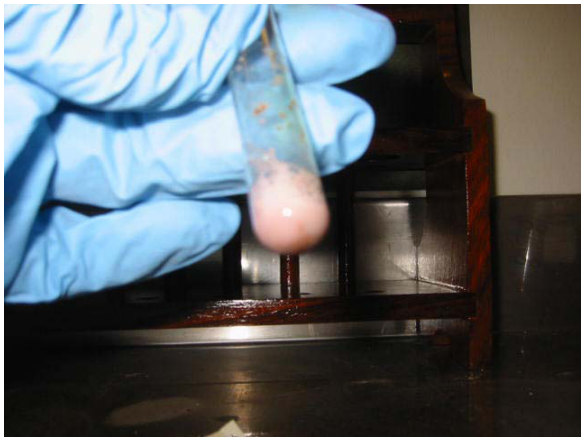
Photo 4 is a photomicrograph taken at 80x of the formation of gypsum needles. The formation of the crystals after the addition of 0.5M nitric acid (NHO_3) and 2M sulfuric acid (H_2SO_4) proved the existence of calcium.



Negative for chlorides

Test for Chlorides

Photo 2 shows the test for chlorides. The pH indicator strip was left in position for 5 minutes. The lack in color change of the strip showed that an acidic volatile gas was not created with the addition of 18N sulfuric acid (H_2SO_4), Thereby showing that chlorides are not present.



Negative for sulfates

Test for Sulfates:

Photo 3 shows the negative result of the nitrate test. A red/pink haze was the result of the addition of 18N sulfuric acid (H_2SO_4) and Iron(II) sulfate ($FeSO_4$).

Interpretation

The presence of calcium (Ca^{+}) and carbonate (CO_3^{2-}) in the sample suggest that calcium carbonate ($CaCO_3$) is the efflorescence seen at 4'6". This salt is found in a number of building materials, including calcareous stone (such as limestone and marble), and mortar components such as lime and cement. The calcium carbonate can be leached out of the masonry by mildly acidic moisture. This moisture could come from acid rain, or be absorbed from the ground below the structure. In order to prevent further efflorescence, and to create a proper plan of action for the removal of the calcium carbonate crust found in the basement the origin of the mineral and the movement of moisture must be better understood. Further testing is needed as recommended below.

Recommended Further Testing

Petrographic Analysis

The mortar is certainly a possible source for the calcium carbonate, but the composition of the building stone must be identified as well in order to determine if its' chemical composition has played a roll in the formation of the efflorescence. This can be done through petrographic analysis by a trained professional.

pH and Soil Tests

The two main potential sources of moisture are acid rain and rising damp. Rain is naturally mildly acidic, but rainfall from around the church may be tested to see if the pH is lower (more acidic) than average. The ground water may also be tested, as well as the soil. Soil type should also be noted at that time to indicate how moisture might move through the local soil.

Effloresence found found in basement